Chapter 7: Dairy Cattle

Dairy cattle include replacement heifer calves and yearlings, dry cows, lactating cows, and breeding bulls used for research and teaching purposes related to milk production. The basic requirements for safeguarding the welfare of dairy cattle are an appropriate husbandry system that meets all essential needs of the animals, and high standards of handling (Agriculture Canada, 1990).

FACILITIES AND ENVIRONMENT

Physical accommodations for dairy cattle should provide a relatively dry area for the animals to lie down in and be comfortable (Cook et al., 2005) and should be conducive to cows lying for as many hours of the day as they desire. Recent work indicates that blood flow to the udder, which is related to the level of milk production, is substantially higher (28%) when a cow is lying than when a cow is standing (Metcalf et al., 1992).

Criteria for a satisfactory environment for dairy cattle include thermal comfort (effective environmental temperature), physical comfort (injury-free space and contact surfaces), disease control (good ventilation and clean surroundings), and freedom from fear. Cattle can thrive in almost any region of the world if they are given ample shelter from excessive wind, solar radiation, and precipitation (Webster, 1983). Milk production declines as air temperature exceeds 24°C (75°F; West, 2003) or falls below −12°C (10°F) for Holstein and Brown Swiss cows or below −1°C (30°F) for Jerseys (Yeck and Stewart, 1959; Young, 1981).

Heat stress affects the comfort of cattle more than does cold stress. Milk production can be increased during hot weather by the use of sunshades, sprinklers, misters, and other methods of cooling (Roman-Ponce et al., 1977; Bucklin et al., 1991; Armstrong, 1994; Armstrong and Welchert, 1994) as well as by dietary alterations (NRC, 1981). Temperatures that are consistently higher than body temperature can cause heat prostration of lactating cows, but additional energy intake (+1%/°C) and greater heat production by the cow can compensate for lower temperatures, even extremely low ones. Consideration also needs to be given to humidity levels and wind chill factors in determining effective environmental temperatures. Adaptation to cold results in a thicker haircoat and more subcutaneous fat, which also reduces cold stress (Curtis, 1983; Holmes and Graves, 1994). Because dairy animals adapt well to cold climates, maintaining indoor air temperature equal to or slightly above outdoor air temperature is quite tolerable to housed animals. Coincidentally, providing the ventilation rate necessary to maintain this minimum temperature difference leads to good air quality (Bickert, 2003b). Protecting the animal from extreme drafts, providing dry lying places that contribute to a dry, fluffy, erect haircoat, meeting the nutritional needs of the animal, and allowing the animal sufficient freedom of movement are essential.

The newborn dairy calf has a lower critical temperature of 8 to 10°C (50°F) (Webster et al., 1978). The intake of high-energy colostrum permits rapid adaptation to environmental temperatures as low as −23°C (−9°F) and as high as 35°C (95°F) in dry, individual shelters with pens (Erb et al., 1951) or in hutches (Jorgenson et al., 1970; Rawson et al., 1989; Spain and Spiers, 1996).

Calves may be housed individually in outdoor hutches or inside buildings in bedded pens or elevated stalls. If calves are exposed to low temperatures, they should be provided with dry bedding and protected from drafts. Proper ventilation is critical in closed buildings with multiple animals. Hutches should be sanitized by cleaning, followed by moving the hutch to a different location or leaving the hutch vacant between calves (Bickert et al., 1994). In hot climates or during hot summer weather, calf hutches need to be environmentally modified or shaded to ensure that the calf does not experience severe heat stress.

Housing and handling systems vary widely, depending on the particular use of the cattle in research and teaching (Albright, 1983, 1987). Recommended facilities for dairy cattle range from fenced pastures, corrals, and exercise yards with shelters to insulated and ventilated barns with special equipment to restrain, isolate, and treat the cattle (Bickert, 2003a). Generally, headlocks (one per cow), corrals, and sunshades are used in warm semi-arid regions. Pastures and shelters are common in warm humid areas. Naturally ventilated barns with free stalls are used widely in both warm and cold regions.

To a lesser extent, insulated and ventilated barns with tie stalls are used in colder climates.

Early research showed an economic advantage in providing housing for dairy cows during the winter instead of leaving them outside (Plumb, 1893). During good weather, to enrich the environment and to improve overall health and well-being, cows should be moved if possible from indoor stalls into the barnyard, where they can groom themselves and one another (Wood, 1977), stretch, sun themselves, exhibit estrous behavior, and exercise (Albright, 1993b). Exercise decreases the incidence of leg problems, mastitis, bloat, and calving-related disorders (Gustafson, 1993).

Keeping cows out of mud and manure increases their productivity and reduces endoparasitic and foot infections. Current trends and recommendations favor keeping dairy cows on unpaved dirt lots in the southwestern United States and on concrete in the northern United States throughout their productive lifetimes. Concrete floors should have a surface texture that provides good footing but does not cause injury (Albright, 1994, 1995a). The concrete surface should be rough but not abrasive, and the microsurface should be smooth enough to avoid abrading the feet of cattle. Scraping a new concrete surface tends to remove microprojections formed during finishing

Data are limited on the long-term effects of intensive production systems; however, concern has been expressed about the comfort, well-being, behavior, reproduction, and udder, foot, and leg health of cows kept continuously on concrete. As a safeguard, cows should be moved from concrete to dirt lots or pasture, at least during the dry period. An additional advantage is that the rate of detection and duration of estrus are higher for cows on recommended dirt lots or pastures than for cows on concrete (Britt et al., 1986).

Exercise during the dry period does not adversely affect milk production, but does result in cows that are fit. Forced exercise after parturition reduces energy intake and milk production; therefore, forced exercise is not recommended (Lamb et al., 1979).

For recommendations for housing cattle in intensive laboratory environments (e.g., lighting, excreta collection, and metabolism or environmental chambers), refer to Chapter 3: Husbandry, Housing, and Biosecurity.

Area

Between and within breeds, ages, and body conditions, critical dimensions of dairy cattle vary less with weight than with age. Body length and hip width are relatively uniform (±5%) across breeds at weights between 180 and 450 kg (400 and 1,000 lb; ASAE, 1987). More than 94% of the dairy cattle in the United States are Holsteins, and area recommendations for female calves and heifers are usually related to age groupings for Holsteins (Woelfel and Gibson, 1978; Graves and Heinrichs, 1984; Heinrichs et al., 1994; MWPS, 1995). Average normal growth curves relate heart girth and live weight to age (Woelfel and Gibson, 1978; Graves and Heinrichs, 1984; Heinrichs et al., 1994; MWPS, 1995).

The length of individual stalls should be a little longer than the length of the animal, defined as the distance between the pin bones and the front of the shoulders (ASAE, 1987) or between the pin bones and the brisket (Irish and Merrill, 1986). For stanchions and tie stalls, stall width to length ratio should be at least 0.7 (MWPS, 1985). The width of free stalls should be twice the hip width (Irish and Merrill, 1986). These dimensions have been taken into account for the recommendations for Holsteins shown in Tables 7-1 and 7-2.

Dairy cows prefer larger, more comfortable stalls and use free stalls 9 to 14 h daily (Schmisseur et al., 1966; Irish and Martin, 1983). Free-stall systems may be adapted for feeding trials utilizing electronic gates. Free stalls are recommended for dairy cattle used in teaching, extension, and research programs throughout much of the United States. The range of effective dimensions of stalls for mature Holstein cows (Graves, 1977; MWPS, 2000) is presented in Tables 7-1 and 7-2.

Bedding

Resting dairy cattle should have a dry bed. Stalls ordinarily should have bedding to allow for cow comfort and to minimize exposure to dampness or fecal contamination. When handled properly, many fibrous and granular bedding materials may be used (MWPS, 2000), including long or chopped straw, poor-quality hay, sand, sawdust, shavings, and rice hulls. Inorganic bedding materials (sand or ground limestone) provide an environment that is less conducive to the growth of mastitis pathogens. Sand bedding may also keep cows cooler than straw or sawdust. Regional climate differences and diversity of bedding options should be considered when bedding materials are being selected. Bedding should be absorbent, free of toxic chemicals or residues that could injure animals or humans, and of a type not readily eaten by the animals. Bedding rate should be sufficient to keep the animals dry between additions or changes. Any permanent stall surfaces, including rubber mats, should be cushioned with dry bedding (Albright, 1983). Bedding material added on top of the base absorbs moisture and collects manure tracked into the stall, adds resiliency, makes the stall more comfortable, and reduces the potential for injuries (MWPS, 2000).

Bedding mattresses over hard stall bases such as concrete or well-compacted earth can provide a satisfactory cushion. A bedding mattress consists of bedding material compacted to 8 to 10 cm (3 to 4 in) and enclosed in a fabric (heavyweight polypropylene or other similar material). Shredded rubber may be used and is recommended as a mattress filler (Underwood et al., 1995). Small amounts of bedding (chopped straw) on

Table 7-1. Recommended options and sizes[1] for pens and stalls for dairy cattle used in agricultural research and teaching

Component	Option	Size	
Individual calves	Hutches and yard or tether	1.5 to 3 m^2/head	6 to 12 ft^2/head
Until 2 mo [to 91 kg (to 200 lb)]	Bedded pen	2.2 to 3 m^2/head	24 to 32 ft^2/head
Until 7 mo [to 182 kg (to 400 lb)]	Stall[2]	0.6 to 0.8 × 1.5 to 1.8 m^2/head	10 to 15 ft^2/head
Groups[3] of weaned calves [182 kg (<400 lb; 3 to 12/group)]	Movable shed (super calf hutch) plus yard	2 m^2/head	21 ft^2/head
	Inside pen	2.3 to 2.8 m^2/head	25 to 30 ft^2/head
	Bedded pack	3.1 × 4.9 to 6.1 m	10 × 16 to 20 ft
	Scraped alley	3.1 × 2.4 to 3.1 m	10 × 8 to 10 ft
Groups[3] of heifers in pens, 6 to 20/group	With free stalls	(see Table 7-2)	
181 to 454 kg (400 to 1,000 lb)	With bedded pack	8 to 12 m^2/t	4 to 6 ft^2/cwt
34 to 136 kg (75 to 300 lb)		1.5 to 5.6 m^2/head	16 to 60 ft^2/head
		5. to 8 m^2/t	2.5 to 4 ft^2/cwt
	With slatted floor[4]	1.5 to 2.3 m^2/head	16 to 25 ft^2/head
	With counterslope		
	Floors and litter alley	6 to 8 m^2/t	3 to 4 ft^2/cwt
		1.5 to 3 m^2/head	16 to 30 ft^2/head
Dry cows and heifers	Bedded pack and paved alley	8 to 12 m^2/t	4 to 6 ft^2/cwt
[454 kg (>1,000 lb)]		4 to 9 m^2/head	40 to 96 ft^2/head
Maternity or isolation pens (5% of cows)[5]	With bedded nonslip floors	9.3 to 14.9 m^2/head	100 to 160 ft^2/head
		3.1 × 3.1 to 3.7 × 4.3 m	10 × 10 to 12 × 14 ft
Individual mature bulls	Rugged pens	13 to 22.3 m^2/head	140 to 240 f^{t2}/head
		3.1 × 4.3 m	10 × 14 ft or larger
	Tie stalls	1.4 × 2.5 to 2.6 m	54 × 97 to 102 in
		to 1.8 × 360 m	to 72 × 188 in
Milking cows	Free stalls	(see Table 7-2)	
	Tie stalls	(see Table 7-2)	
	Paved lots	9 m^2/head	100 ft^2/head
	Unpaved corrals	46 m^2/head	500 ft^2/head

[1]Sizes exclude access for feeding and cleaning.
[2]Research protocol may require the use of individual stalls for calves.
[3]Different sources use different age groups. Weight variation increases with age.
[4]Space decreases with age. Spacing between slats is 3.18 cm at 169 kg, 3.82 cm at 170 kg, and 4.45 cm at 250 to 500 kg (1.25 in at 374 lb, 1.5 in at 375 lb, and 1.75 in at 550 to 1,100 lb; Woelfel and Gibson, 1978).
[5]In addition to maternity pens, treatment and handling facilities are recommended (Anderson, 1983; Anderson and Bates, 1983; Bates and Anderson, 1983; Graves, 1983; Veenhuisen and Graves, 1994; MWPS, 1995).

top of the mattress keep the surface dry and the cows clean (MWPS, 2000).

Ventilation

Ventilation permeates all aspects of the animal environment (Bickert, 2005). Most often, ventilation is associated with respiratory health of animals: the quality of the air that animals breathe directly influences animal health and disease. Nevertheless, ventilation—directly and indirectly—affects many other aspects of animal health as well. Good ventilation in the lying area of lactating animals helps to keep bedding dry, a factor in favor of good mammary health. Good ventilation along alleys helps to keep walking surfaces dry, a condition that contributes to healthy feet and a reduction in falling accidents. Good ventilation may lead to greater productivity; for example, maintaining air movement in the area of the eating area makes animals more comfortable, which is especially important during hot weather as an aid to maintaining dry matter intake. A comfortable, well-ventilated lying area encourages animals to lie down, an important contribution to many aspects of animal health (rumination, mammary blood supply).

During ventilation, outside air is brought into a barn where it collects moisture, heat, and other contaminants, all produced by the animals. Air is then exhausted to the outside. Ventilation is an air exchange process—contaminated air inside the barn is exchanged for fresh outside air. To determine ventilation rates, we focus on the moisture content of the air, as measured by relative humidity. But moisture is only one aspect; ventilation removes other undesirable contaminants as well.

Ventilation is truly a process of dilution. Air moved through a barn actually serves to dilute the inside air and, very importantly, to dilute all of its components. Dilution reduces concentrations of moisture and heat. Dilution also reduces concentrations of airborne disease organisms, harmful gases and dust, and undesirable odors. The dilution rate of ventilation is often expressed in air changes per unit time. For example, a ventilation rate of 4 air changes per hour implies that the entire

volume of the ventilated space (e.g., a barn) is replaced every hour. In fact, some of the air may bypass the occupied zone in the barn, depending upon geometry of the space, the design of diffusers controlling inlet air, and so on. Thus, the effectiveness of ventilation is not often 1.0, but something less, perhaps 0.65.

When ventilation is reduced below recommended levels—usually in a misguided effort to warm the barn using animal heat—less moisture is removed. Sometimes the consequences of the resulting moisture buildup and lack of proper ventilation—usually condensation—are masked by 1) insulating the barn, 2) using a greenhouse effect, 3) providing supplemental heat, or 4) dehumidifying the inside air. For example, adding heat to the air reduces relative humidity, without the need for air exchange. It is quite possible to have substantial quantities of moisture added to the air and, if accompanied by heating of the air, have the relative humidity remain in an acceptable range. Thus, if relative humidity is the only measure of air quality, air quality may be deemed satisfactory. However, even though excess moisture may not be apparent, the reduced dilution does indeed result in increased concentrations of airborne disease organisms, harmful gases and dust, and undesirable odors. If these increases are ignored, animal health problems are inevitable.

Underventilation in winter is one of the most serious threats to the environment of animals. Improper design and improper management of the ventilation may be reasons that wintertime ventilation is lacking, compromising animal health. Problems are most likely during winter, spring, and fall, especially during rainy weather and warmer days coupled with cold nights. Specific recommendations for ventilation system design are available (MWPS, 2000). In general, minimum ventilation is provided by a continuous rate in winter, amounting to at least 4 to 6 air changes per hour. Summer ventilation rates may range up to and above 90 air changes per hour.

Maintaining good air quality is a fundamental aspect of that healthy environment with ventilation providing the key. Through ventilation, the air inside the barn is continually diluted, ensuring that the air the animal breathes has low concentrations of all contaminants that threaten the animal's health.

Housing Types

In colder climates, stanchion and tie-stall barns have served well for herds ranging up to 50 or 60 milk cows. However, stall barns are labor intensive, both for milking and feeding. Comfort or tie stalls are preferred over stanchions. To avoid contamination of the teat and reproductive tract orifices, manure removal must be more regular and thorough when cows are housed in tie stalls. Cow trainers and gutter grates are recommended to ensure cleaner stalls and cows.

Free-stall barns are a type of loose housing with one free stall recommended for each lactating cow. Depending upon provisions for feeding, different groups of cows can be fed differently according to their particular nutritional requirements. This has led to barn arrangements that permit division of milking herds into groups, usually by production.

One free stall is recommended for each lactating cow. The stall base and bedding provide a resilient bed for cow comfort and a clean, dry surface to reduce the incidence of mastitis. Because cows prefer to stand uphill, the stall base should be sloped forward 3 to 4% from rear to front. Commonly used materials for the base include concrete, clay, sand, and stone dust; hardwood planks tend to rot. Rubber tires, if not firmly imbedded, tend to become loose (MWPS, 1995). In an ideal free stall, the stall bed and partition should define the lying position of the cow and accommodate natural lying and rising behavior (McFarland and Gamroth, 1994; MWPS, 2000).

Proper free-stall care includes daily inspection and removal of wet bedding and manure, in addition to adding dry bedding periodically. Neglected free stalls with excessive moisture or accumulations of manure can lead to an increased incidence of mastitis. For stalls with bases that must be replenished such as sand, an upward slope of the base toward the front should be maintained. This upward slope helps position cows more squarely in the stall when lying down, which contributes to cleaner stalls and cleaner cows. Free-stall hardware and other components should be kept in good repair.

Corrals should be scraped as needed and concrete alleys should be scraped or flushed regularly to clean them effectively. Feedbunk areas should be scraped regularly and any leftover feed removed. Shades and corrals should be designed to minimize areas of moisture and mud.

Pastures must be managed to avoid disease transmission. Stocking rates should maximize production per head unless forage supplementation is provided or unless production per unit of pasture area is to be studied. This strategy minimizes the stress that may result from overgrazing and minimizes ingestion of plants from areas immediately surrounding those areas contaminated with excreta, thereby reducing the challenge of potential pathogens and helminth parasites. Some pathogenic microbes may survive more than 6 mo in fecal deposits. Shade should be provided during hot weather.

Special Needs Areas

Cows with special needs are associated with greater risk and thus require special consideration with respect to facilities (Bickert, 2003a):

- Preparturition. Cows that are near the time of calving (2 to 3 wk prepartum) benefit from a clean, dry environment and access to an appropriate dirt lot for exercise. Feeding facili-

ties should be provided to prepare cows for the high-energy ration they will receive upon entering the milking herd. Free-stall housing situated for frequent observation and proximity to the maternity area is a desirable option.

- Maternity. In preparation for calving, cows should be moved to individual pens that are separate from other animals, especially younger calves. The environment should be well ventilated, and the pens should be maintained to be clean, dry, and well bedded. Recommended pen size is 3.7 m × 3.7 m or 3 m × 4.3 m (12 ft × 12 ft or 10 ft × 14 ft). The maternity pen should have a stanchion on one side for cow restraint. A concrete curb between each stall aids sanitation. Deep bedding should be used on concrete floors to prevent cows from slipping. Grooved concrete (e.g., diamond pattern) is also recommended (Albright, 1994, 1995a). Provisions should exist for lifting downer cows. Devices to aid and promote standing include hip lifters (hip clamps), slings (wide belt and hoist), inflatable bags, and warm water flotation systems. Pen location should permit access by a tractor or loader to allow removal of downed cows. All downed cows should be promptly examined by a veterinarian and handled in a humane and appropriate manner. Each pen should be provided with adequate feeding space and fresh, clean water. Depending on local conditions, a calving pen may not be necessary. Cows can calve in a pasture area with lighting situated for observation. A calving pasture should be well sodded and drained, should be large enough to allow cows to move away from others in the group before calving, and should contain an adequate sheltered area. Use of a pasture pen can eliminate footing and bedding problems associated with calving pens.
- Removing calf. Dairy calves are normally removed from their dams as soon as possible following birth. The cow and calf are more difficult to separate after 3 d (Albright, 1987). Therefore, early removal (before 72 h) is recommended (Hopster et al., 1995). To prevent transmission of Johne's disease, follow the National Johne's Education Initiative control program (www.johnesdisease.org; accessed June 16, 2009).
- Postcalving. A cow that has recently calved (from 0 to 7 d postpartum) should be placed in a special area for frequent observation before rejoining the milking herd. Individual feed intake and milk production should be monitored to determine whether the cow is progressing normally. Milk must be withheld from shipment as required by regulations. Free stalls or large, well-bedded pens may be used in this special area. For a larger herd, a special hospital and maternity barn, possibly equipped with a pipeline or portable milker, could house cows in this management category as well as cows that are calving or that have other special needs.
- Treatment. A treatment area in the barn is recommended for confining cows for artificial insemination, pregnancy diagnosis, postpartum examination, sick cow examination, surgery, and for holding sick or injured animals until recovery.
- Dry-off. Cows recently dried off should be separated from the milking herd for feeding purposes. Recommended medical treatments should be performed, and cows should be observed frequently to ensure normal progress.

Lighting

Lighting recommendations for dairy cattle housed in indoor environments are the same as those for beef cattle in intensive environments (see Chapter 6: Beef Cattle).

FEED AND WATER

Except as necessary for a particular research or teaching protocol, dairy cattle should be fed diets that have been formulated to meet their needs for maintenance, growth, production, and reproduction (NRC, 2001; see Chapter 2: Agricultural Animal Health Care). Feed ingredients and finished feeds should be wholesome, carefully mixed, and stored and delivered to the cattle to minimize contamination or spoilage of feeds. To ensure freshness, feeds that are not consumed should be removed daily from feeders and mangers, especially high-moisture feeds such as silage. Feed should be far enough from waterers to minimize wetting of feed.

Space should be adequate for feed and water. Feeders or mangers should be designed with smooth surfaces for easy cleaning and increased feed consumption. The recommended linear space per cow at the feed bunk is 61 to 90 cm (2 to 2.5 ft), which should allow every animal uninterrupted feeding (Malloy and Olson, 1994). Feeder design should permit a natural head-down grazing posture to promote intake, improve digestive function, facilitate normal tooth wear, and decrease feed-wasting behavior (Albright, 1993a). At least one water space or 61 cm (2 ft) of tank perimeter should be provided for every 15 to 20 cows in a group. At least 2 watering locations should be provided for each group of cows. Each cow in tie stalls and stanchions should have its own water bowl or drinking cup (Andersson, 1985; MWPS, 1995).

All calves should consume colostrum in amounts of 8 to 10% of body weight (or 2 to 3 L) within 4 to 5 h after birth always before milk is fed, and another 2 to 3 L within 24 h of birth for a 36- to 45-kg (80- to 100-lb) calf (Stott et al., 1979; Stott and Fellah, 1983; Hunt, 1990; Pritchett et al., 1991; Mechor et al., 1992).

Colostrum should be monitored with a colostrometer for quality (protein and antibody content). Mixed high-quality colostrum pooled from several cows can be better than low-quality colostrum from a particular dam. However, it is currently suggested that individual cows be tested for colostrum quality for the use of their colostrum alone with avoidance of colostrum from known disease-carrying cows (e.g., those with Johne's disease, mycoplasma, or bovine viral diarrhea; Stabel, 2009). Proper handling and storage of the colostrum is essential. Until calves can consume dry feed at an adequate rate, they should be fed liquid feed in amounts sufficient to provide needed nutrients at a rate up to 20% of body weight at birth per day until weaned. Water should be given at times other than when milk or milk replacer is fed to avoid possible interference with curd formation. However, this is not a problem with most milk replacers currently fed. Fresh water should be provided at all times. Replenishment of water should follow milk or milk feeding by at least 15 minutes (Davis and Drackley, 1998). Calves being raised as replacement heifers or for beef should be fed enough dry feed with sufficient fiber preweaning to stimulate normal rumen development (McGavin and Morrill, 1976). Calf research guidelines have been reported that permit uniformity in measuring and reporting experimental data (Larson et al., 1977).

Water intake affects consumption of dry matter (Kertz et al., 1984; Milam et al., 1986) and is itself influenced by individual behavior, breed, production rate, type and amount of feed consumed, water temperature, environmental temperature, atmospheric vapor pressure, water quality, and physical facility arrangement (Atkeson and Warren, 1934; Murphy et al., 1983; Andersson, 1985; Lanham et al., 1986). Nonlactating cows consume 3 to 15 kg of water/kg of dry matter consumed, depending on environmental temperature. Lactating cows consume 2 to 3 kg of water/kg of milk produced plus that required for maintenance (Little and Shaw, 1978).

Water should be available at all times (NRC, 2001); it should be checked daily for cleanliness and monitored regularly to ensure that it is free of contaminants that could potentially put zoonotic agents into the human food chain (Johnston et al., 1986). Water sources should be readily accessible to all stock. Underfoot surroundings in watering areas should be dry and firm. Cattle should not be able to wade in drinking water.

HUSBANDRY

Social Environment

Dairy cattle are social animals that exist within a herd structure and follow a leader (e.g., to and from the pasture or milking parlor). Cows exhibit wide differences in temperament, and their behavior is determined by inheritance, physiology, prior experience, and training. Cattle under duress may bellow, butt, or kick; however, cows are normally quiet and thrive on gentle treatment by handlers. Cows learn to discriminate among people and react positively to pleasant handling. Aversive handling leads to more incidents during handling and transport for calves than positive handling (Lensink et al., 2001). Similarly, heifers and cows exposed to aversive handling took longer to traverse and more force to move than those handled more gently (Pajor et al., 2000). Although the presence of an aversive handler reduced kicking during udder preparation, residual milk was 70% greater than for the control milkings (Rushen et al., 1999a). Cows have higher milk yields if handlers touch, talk to, and interact with them frequently (Albright and Grandin, 1993; Seabrook, 1994).

Cows should have visual contact with one another and with animal care personnel. Handling procedures are more stressful for isolated cattle; therefore, attempts should be made to have several cows together during medical treatment, artificial insemination, or when cows are being moved from one group to another (Whittlestone et al., 1970; Arave et al., 1974). This was verified by increased heart rate, hypothalamic-pituitary-adrenocortical axis activity, and vocalizations. Pain sensitivity is reduced during isolation, suggesting a stress-induced analgesia (Rushen et al., 1999b). Care should be taken to minimize the negative impact of moving cows to new groups by avoiding frequent regrouping and by always moving more than one animal at a time to a new group. The use of a trainer cow can have a positive impact on adjustment to feedlot environments where many heifers are raised (Loerch and Fluharty, 2000). However, dairy calves had few indicators that repeated regrouping and relocations stressed calves. Aggression was rare and the calves seemed to habituate to the repeated mixing (Veissier et al., 2001). Calves from larger groups after weaning (16 compared with 4) had fewer incidences of displacement of other calves from the feed barrier, were more active, and had more positive interactions with familiar calves (Færevik et al., 2007). Calves, like cows, prefer familiar calves to unfamiliar calves during stressful situations, and a familiar companion calf improved cows' reaction to separation (Færevik et al., 2005). Social status can affect health issues such as lameness (Galindo and Broom, 2000). Low-ranking cows spent more time standing and standing half in cubicles (perching) than did middle- and high-ranking cows. Standing half in cubicles correlated positively with the number of soft tissue lesions related to lameness.

Dairy cattle have traditionally been kept in groups of 40 to 100 cows (Albright, 1978), although specific research protocols may require smaller or larger group sizes. Variation in group size—small (50 to 99), medium (100 to 500), and large (500 or more)—does not cause a problem per se. Expansion to a larger herd size, however, can affect management decisions because overcrowding with an insufficient number of headlocks or inadequate manger space per cow, irregular or infre-

quent feeding, and excessive walking distance to and from the milking parlor have a greater impact on behavior and well-being than does group size (Albright, 1995b).

Cattle of all ages are gregarious. Socially isolated cattle show clear signs of stress: increased heart rate, vocalization, defecation/urination, and cortisol levels (Rushen et al., 1999a; Herskin et al., 2007). In addition, there are benefits of housing cattle together. For example, pairs of calves are more likely to play than isolated calves, a behavior thought to be associated with positive welfare (Jensen, 2004). Young calves should be kept in groups from 2 to 7 animals in order for animals to benefit from social contact, but larger groupings are associated with health problems and morbidity (Losinger and Heinrichs, 1997; Svensson et al., 2003). Management of resources is an important part of reducing aggression and other problems, such as cross sucking, in groups of animals. Adult dairy cattle should have 1 freestall/cow to reduce competition (Fregonesi et al., 2007). Similarly, dairy cattle with more space at the feedbunk (1.0 vs. 0.5 m) engage in fewer aggressive interactions (DeVries et al., 2004), and the reduction of competitive behavior associated with more feeder space is particularly marked in post-and-rail feeder design (Huzzey et al., 2006).

Cross sucking in calves is an undesirable behavior performed in groups. Calves are typically fed 10% body weight during the milk-fed period and there is clear evidence that this feeding level is insufficient (Jasper and Weary, 2002; Khan et al., 2007). A combination of slower milk flow, hay feeding, and access to a non-nutritive artificial teat are also recommended to reduce cross sucking (de Passillé, 2001). Providing additional objects for oral manipulation, such as tires, has also been shown to reduce other problems such as stereotypic tongue rolling in calves (Veissier et al., 1998).

Restraint and Handling

Vaccination schedules that are appropriate for the location and dynamics of the individual herd should be established with the advice of the attending veterinarian. Certain dairy cattle behaviors (e.g., aggression and kicking) put at risk the health and well-being of herdmates as well as the humans handling the cattle. These behaviors can be reduced or modified by implementing principles of low-stress handling and restraint (Grandin 1993) that include appropriate movement of people, well-designed facilities, optimal lighting, nonslip flooring, and smooth, quiet restraint devices. Stanchions, head gates, and squeeze chutes can be modified to function optimally, but acclimation and positive reinforcement by individuals trained in low-stress handling can minimize the need for additional restraint by halters, rope, tail hold, and nose tongs. Hobbles and casting ropes should be used selectively and only when necessary. Chemical sedation is always preferable to excessive use of force or application of electrical prods.

Information about calving management is given by Albright and Grandin (1993). First-calf heifers should be bred to calving-ease bulls and be of appropriate stature and body condition to minimize the chances of dystocia or the need for calving assistance. Optimal calving conditions in a clean, quiet environment with employees appropriately trained to follow calving protocols will result in more live calves and fewer calving injuries and illness. Calving injuries should be assessed immediately so that appropriate footing is provided and proper treatment is implemented. Cows that are unable to stand should be moved to a soft-bedded pack and examined by a veterinarian within 2 to 4 h of calving.

Calves require special handling and care from the time they are born. Colostrum should be fed or ingested within the first 5 h after birth always before milk is fed. Between 1.89 L (2 quarts; for beef-breed calves) and 3.79 L (4 quarts; for most dairy calves) of colostrum are necessary to impart adequate immunity to the calf. In the absence of colostrum, a colostrum replacement product that delivers at least 125 g of immunoglobulin should be given by bottle, bucket, or tube feeder. Colostrum is rich in nutrients and provides the calf with vital immunoglobulins and other important immune factors. Clean navels can be dipped in a dilute chlorhexidine solution (1 part of a 2% chlorhexidine solution mixed in 4 parts water) as soon as possible after birth. Good nutrition as supplied by a combination of milk (or milk replacer), starter grain, and fresh water along with proper handling and close monitoring starts a calf on its way toward a healthy life.

STANDARD AGRICULTURAL PRACTICES

All animals should be individually identified (see Chapter 2: Agricultural Animal Health Care). Heifer calves should have supernumerary teats removed at an early age (Moeller, 1981). Removal may be performed in the first 3 mo of life with a scalpel or sharp scissors. Older calves and heifers close to calving that have supernumerary teats should be examined by a qualified person. The removal of extra teats at this advanced age is necessary if they will later disrupt the milking process or be at risk of becoming infected. If so, they can be removed with proper restraint and use of appropriate anesthesia by a qualified and trained person. Milking procedures should follow National Mastitis Council guidelines (NMC, 2007). Routine breeding programs should include housing and handling facilities that allow for effective implementation of artificial insemination programs.

Castration may be performed on male calves (see Chapter 6: Beef Cattle).

Disbudding and Dehorning

A review of horn anatomy and growth and dehorning and disbudding of cattle was provided by the AVMA (2007b). The AVMA also provides guidance on use of sedation, anesthesia, and analgesia and alternatives to horn removal (AVMA, 2007b). The AVMA policy on dehorning/disbudding should be followed (AVMA, 2008).

Calves should be observed closely for 1 to 2 h following dehorning. No food or water should be offered until the sedation is completely worn off or reversed. Persistence of a depressed attitude, head-pressing, or an abnormal head tilt for more than 2 h should result in a complete examination.

Tail Docking

The bovine tail has several physiological and behavioral functions including dissipation of heat, and facilitation of visual communication among cattle and with human caretakers; the tail often serves as a primary mechanism of fly control (Stull et al., 2002). Removal of the lower portion of a cow's tail is commonly referred to as "tail docking" and the use of tail docking as a routine dairy farm management tool apparently originated in New Zealand. New Zealand farmers responding to a 1999 survey believed removal of tails resulted in faster milking, reduced risks to the operator, and reduced rates of mastitis (Barnett et al., 1999). Similar unsubstantiated claims have been made for the US dairy industry (Johnson, 1991). Several European countries, some Australian states, and California have prohibited tail docking. Both the Canadian and American veterinary medical associations have policy statements that oppose the practice of tail docking for routine management of dairy cattle (AVMA, 2006). The policy statement of the American Association of Bovine Practitioners (**AABP**) indicates that scientific evidence to support tail docking is lacking and recommends that "if it is deemed necessary for proper care and management of production animals in certain conditions, veterinarians should counsel clients on proper procedures, benefits, and risks (AABP, 2005). Scientific studies have been performed to evaluate both the potentially negative and positive aspects of tail docking. Important welfare issues that have been evaluated have included pain caused by tail docking, changes in fly avoidance behavior, immune responses, and changes in levels of circulating plasma cortisol (Petrie et al., 1996; Eicher et al., 2000, 2001, 2006; Eicher and Dailey, 2002; Schreiner and Ruegg, 2002a; Tom et al., 2002). Experiments that have been performed on both calves and preparturient heifers have consistently concluded that the process of tail docking does not induce significant acute or chronic changes in plasma cortisol or other selected physiological measures (Matthews et al., 1995; Petrie et al., 1996; Eicher et al., 2000; Schreiner and Ruegg, 2002a; Tom et al., 2002). Modest changes in general behavior of calves that have been docked using rubber rings or cautery irons have been reported but these changes have not been associated with significant differences in normal feeding, ruminating, or grooming behaviors (Petrie et al., 1995; Schreiner and Ruegg, 2002a; Tom et al., 2002). Likewise, few significant differences in general behavior of docked preparturient heifers have been noted (Eicher et al., 2000; Schreiner and Ruegg, 2002a). However, greater changes have been observed in tail surface temperatures of docked heifers compared with heifers with intact tails, indicating that heifers may experience chronic pain similar to the phantom pain reported by human amputees (Eicher et al., 2006).

Research has demonstrated that tail-docked heifers flick their tails more often and are forced to use alternative behaviors such as rear leg stomps, feed tossing, and head turning to try to rid themselves of flies (Ladewig and Matthews, 1992; Phipps et al., 1995; Eicher et al., 2001). More flies settle on tail-docked cows than on intact cows, and the proportion of flies settling on the rear of the cow increases as tail length decreases (Matthews et al., 1995). In another study (Eicher et al., 2001), there were no significant differences in the numbers of stable flies found on the front legs of cows but docked cows had nearly twice as many flies on their rear legs compared with those with intact tails . Fly avoidance behaviors (such as feed tossing) were increased in the docked animals, whereas tail swinging was increased in the control animals. Foot stamping was identified only in docked animals and, overall, fly numbers and fly avoidance behaviors were increased in docked animals (Eicher et al., 2001). Researchers have been unable to identify improvements in udder health or udder cleanliness for animals in commercial herds that have docked tails (Tucker et al., 2001; Schreiner and Ruegg, 2002b). In one study, the effect of tail docking on cow cleanliness and somatic cell counts (**SCC**) was evaluated over an 8-wk period for lactating cows that were housed in a free-stall facility (Tucker et al., 2001). Standardized cleanliness scores obtained from the rump, midline of the back, or rear udder were not significantly different between docked and intact animals nor was there any significant difference in SCC or the number of teats containing obvious debris (Tucker et al., 2001). In another study, SCC, occurrence of intramammary infections (**IMI**), and udder and leg hygiene scores were evaluated over an 8-mo period for lactating dairy cows (n = 1,250) that had been blocked by farm (n = 8) and randomly allocated to tail-docked or control groups (Schreiner and Ruegg, 2002b). No significant differences were found in SCC or udder and leg hygiene scores. The prevalence of contagious, environmental, and minor pathogens was not significantly different between cows with docked or intact tails. Although current studies do not indicate that the process of tail docking modifies physiological indicators of stress, several studies have documented changes in fly avoidance behavior and recent research has suggested that docked tails have en-

hanced sensitivity to heat. No benefits to cattle welfare have been associated with tail docking. The routine use of tail docking in research or teaching herds should be discouraged, and alternatives to tail docking (such as trimming switches with clippers or fastening the switch out of the way) are recommended when appropriate. Any use of tail docking, other than for medical reasons, should be reviewed and approved by the IACUC.

Foot Care

Lameness in dairy cattle is a major source of economic loss to the farmer and a serious cause of pain and discomfort to the cow. It is perhaps the most important condition affecting the welfare of cows on dairy farms (Cook, 2003; Espejo et al., 2006; Vermunt, 2007). Lame cows suffer lowered milk production and reduced fertility, and are culled at 2 to 4 times the rate of healthy control cows (Cook et al., 2004). The pain associated with lameness results in changes in the animal's gait that include

1. Arching of the back (in cases of rear limb lameness);
2. Shortening of the stride length on the affected limb (as the cow tries to reduce the time spent weight bearing on the painful limb);
3. Sinking of the dew claws on the unaffected contralateral limb (as the cow transfers weight to the unaffected side);
4. Head bob in a vertical plane (the head is raised as the painful foot strikes the ground, especially with front limb lameness and may be reversed with rear limb lameness);
5. Reduction in walking speed, and frequent stops; and
6. Swinging the affected limb in or out depending on the location of the painful lesion.

These alterations can be used to provide a locomotion score for each animal, and the most commonly used system in North America utilizes a 5-point system of scoring where 1 is nonlame and 5 is severely lame. Herd workers should be taught how to score locomotion so that they can identify cows with scores >2 for treatment by an attending veterinarian or hoof-trimmer (Bicalho et al., 2007).

Around 85% of lameness in dairy cattle is associated with lesions in the rear feet, particularly the outer claw, because of the overgrowth of horn resulting from the redistribution of weight as the cow walks on hard concrete surfaces, with a large udder occupying the space between her rear legs. This overgrowth of the outer claw may be removed and the weight transferred equally between the inner and outer claw by regular hoof-trimming. Trimming to restore a normal toe length along the dorsal hoof wall of around 75 mm (3 in) for mature Holstein cattle, combined with balancing weight between the inner and outer claw, lasts around 4 mo on average. Therefore, it is recommended that cattle be trimmed at 6-mo intervals, typically at the time of dry off and in mid-lactation around 90 to 150 d in milk. Some cows with pre-existing hoof disease may require attention more frequently (every 2–4 mo).

Hoof lesions causing lameness may be broadly classified into 2 groups: infectious and claw horn. Infectious lesions include digital dermatitis (heel warts), interdigital phlegmon (foot rot), and heel horn erosion. These lesions are associated with poor feet and leg hygiene and are a particular problem in free-stall environments, where the cow is exposed to alleyways contaminated with wet manure when she is not occupying a stall. Putative agents such as several species of *Treponema* and *Fusobacterium necrophorum* are involved in the pathogenesis of these conditions, but hydropic maceration of the skin of the interdigital space appears to be a prerequisite for the development of disease (Berry, 2006). Infectious causes of lameness are controlled by improving leg hygiene by removing manure from the walkways and by the use of a topical antibacterial administered either directly to the lesion by a hand-held spray or via a footbath. The frequency of foot bathing is dependent on the degree of manure contamination of the cows, and a variety of chemicals are available for use, such as copper sulfate, zinc sulfate, and formalin. Use of any of these chemicals should be done under veterinary direction.

Claw horn lesions include sole hemorrhage, sole ulcer, toe and heel ulcer, and white line disease (including hemorrhage, fissure, and abscess). These are clinical signs on the surface of the claw that represent the result of several possible causative pathways. Sinking of the third phalanx within the claw horn capsule, due to a breakdown in the connective tissue of the suspensory apparatus, may be caused by hormonal changes at calving time and nutritional events such as subacute ruminal acidosis (Cook et al., 2004). Sinking of the third phalanx compresses the corium below, interrupting the flow of blood and nutrients to the cells responsible for horn growth. As a result, a defect develops that becomes apparent several months later as the sole horn continues to grow.

Excessive removal of sole horn, either through poor hoof trimming or due to excessive wear from walking long distances on rough concrete will also contribute to lesion development. Flooring surfaces should be nonslip, avoid excessive trauma to the claw surface and be dry. Concrete should be grooved to improve traction; a pattern that utilizes parallel grooves 3/4 inch wide and deep, spaced 3 inches on center appears to provide a good compromise between sufficient traction to reduce injury while limiting the amount of wear. For transfer lanes between milking centers and the living accommodation, a 1-m (30-inch)-wide strip of rubber flooring has been used successfully to reduce trauma and wear, and rubber flooring has been used in parlor holding areas to provide cushion for cows that have to stand for long periods of time (Cook and Nordlund, 2009).

The severity of the claw horn lesions that develop is influenced by the time spent standing each day, which results in increased loading of the claw and increased compression of the tissues below the third phalanx. Time spent standing may be increased by 1) poor stall designs that fail to provide surface cushion, room to lunge, and sufficient resting area; 2) overstocking—providing fewer usable stalls than there are cows in a pen; 3) excessively prolonged milking times (>45 min per milking); 4) time spent locked up away from the stalls for management tasks (>2 h); and 5) heat stress—cows may stand more in an attempt to cool off.

In addition, lame cows struggle to use stalls with hard surfaces because the act of rising and lying down becomes more challenging due to foot pain (Cook and Nordlund, 2009). These cows stand more in the stall and fail to gain adequate rest for lesion healing. For this reason, deep sand-bedded stalls provide the gold standard in cow comfort. If sand stalls are unavailable, lame cows should be treated and returned to a bedded pack area for rest and recuperation until normal ambulation returns.

Failure to identify a claw horn lesion early in its course may result in deep digital sepsis. This is a complication caused by infection of the deeper structures of the claw, including the distal interphalangeal joint and tendon sheaths. Such animals are usually severely lame and require euthanasia or extensive surgery (requiring months for recovery). Seeking veterinary assistance is recommended for individual cows that show signs of lameness or if a significant lameness issue exists for the herd.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of dairy cattle environments.

HANDLING AND TRANSPORTATION

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of dairy cattle.

SPECIAL CONSIDERATIONS

Milking Machine and Udder Sanitation

The milking facility should have a program for regular maintenance of milking machines and follow the recommended mastitis control program of the National Mastitis Council (NMC, 2007). Appropriate equipment and competent personnel should be available for milking. Personnel responsible for milking should receive ongoing training about proper milking procedures as the frequency of training has been associated with adequacy of milking performance (Rodrigues et al., 2005). Animal care facilities should be designed and operated to standards meeting or exceeding those of grade A dairies as defined in the Pasteurized Milk Ordinance (FDA, 2004). Areas where milking takes place (whether in a barn or milking parlor), must be designed and constructed in accordance with the 3-A Sanitary Standards Inc. (2009) Accepted Practices. Cows should be maintained in housing areas that provide for adequate hygiene to ensure that udders are visibly clean. Cows should be milked on a regular schedule that is appropriate for the goals of the herd or specific research project. Written operating procedures should be established to control potential contamination of milk with antibiotics or other pharmaceutical agents. Antimicrobial treatments should be administered based on approved defined protocols. All extra-label treatments must be administered under the supervision of a veterinarian that has an appropriate veterinary-client-parent relationship. Milking machine and udder sanitation are vital to an effective preventive program against mastitis and follow guidelines as established by the NMC (1993). Care should be used to minimize the excessive use of water before and during udder preparation. Emphasis should be placed on ensuring that cows enter the milking parlor with clean, dry teats. Udders, especially teat ends, should be clean and dry when teat cups are applied for milking. The removal of foremilk ("forestripping") before teat disinfection is encouraged as a means to detect mild cases of clinical mastitis. Teat sanitation, predipping, and wiping immediately before machine attachment reduce udder infection caused by environmental pathogens (Bushnell, 1984; Pankey et al., 1987; Galton et al., 1988; Pankey, 1992; Malloy and Olson, 1994; Reneau et al., 1994). Postmilking disinfection of teats is an essential management practice that greatly reduces the incidence of mastitis (Neave et al., 1969; Philpot et al., 1978a,b; Philpot and Pankey, 1978; Pankey, 1992). Milkers handling cows should pay meticulous attention to their own personal hygiene and wash their hands thoroughly before milking and frequently during milking. The use of clean nitrile or latex gloves during milking is highly encouraged to prevent contamination of the udder. Cows with subclinical cases of contagious mastitis should be milked last to reduce the spread of mastitis throughout the herd. Udder hair removal is recommended as a means to improve milking hygiene and udder health. Cleaning of milk handling equipment is accomplished by a combination of chemical, thermal and physical processes and cleaning regimens should be designed to meet appropriate regulatory standards. Recommended cleaning and sanitizing practices are a balance between the cleaning temperatures, cleaning chemical concentration, contact time and mechanical action (Reinemann et al., 2000). Effective cleaning programs for milking machines include use of hot water (typically between 38 and 55°C); use of disinfectant solutions and other chemical agents

effective for removing mineral, milk fat, and protein deposits from equipment between milkings; disinfection of teat cups between cows; and flushing of teat cups with warm water, cold water, boiling water, or chemical disinfectant solution. The most common routine in the United States is a combination of prerinse, alkaline detergent, acid rinse (frequency depending on water hardness), and premilking sanitize. Very small herds (<30 cows) may utilize manual cleaning and disinfecting that involves hand-cleaning of some or all of the milk harvesting and storage equipment. Small to medium herds (30 to 500 cows) commonly use automatic washing equipment. This equipment will automatically mix the chemicals with the appropriate water volume and temperature and circulate these solutions through the milking machine. On large farms (1,000 cows or more), an attendant may be present to mix chemical solutions and operate valves for circulation. The effectiveness of milking system cleaning can be evaluated by examination of standard plate counts and laboratory pasteurized counts performed on bulk tank milk samples.

Stray Voltage

The term stray voltage describes a special case of voltage that develops on grounded metal objects on farms. If this voltage reaches sufficient levels, animals coming into contact with grounded devices may receive a mild electrical shock that can cause a behavioral response. At voltage levels that are just perceptible to the animal, behaviors indicative of perception such as flinches may result, with little change in normal routines.

Studies by numerous independent research groups in several countries are in agreement that the most sensitive cows (<1%) begin to react to 50 or 60 Hz electrical current of 2 mA (measured as the root mean square average; rms) applied from muzzle to hooves or from hoof to hoof (Lefcourt, 1991; Reinemann, 2005). This corresponds to a contact voltage level of about 1 V (50 or 60 Hz, rms). As the voltage and current is increased, a greater percentage of cows will react with behavioral responses becoming more pronounced. Numerous studies have documented avoidance behaviors at levels above the first reaction threshold. The median avoidance threshold for 50 or 60 Hz current flowing through a cow is about 8 mA (4 to 8 V, rms). Even when the threshold is exceeded not all cows would be expected to show a behavioral response but as the voltage increases, signs in a herd would be expected to be more widespread and uniform.

The scientific evidence strongly suggests there is no relationship between behavioral responses to stray voltage and physiological or hormonal responses. There is no apparent relationship among behavioral modifications, milk production, and animal health. The only studies that have documented adverse effects of voltage and current on cows had both sufficient current applied to cause aversion and forced exposures (animals could not eat or drink without being exposed to voltage/current). It is typical for voltage levels to vary considerably at different locations on a farm. Decreased water and(or) feed intake or undesired behaviors will result only if current levels are sufficient to produce aversion at locations that are critical to daily animal activity. These locations include feeders, waterers, and milking areas. Controlled research has shown that if an aversive voltage was administered to a water bowl once per second, water intake was reduced. However, when the same voltage was applied once every 10 min and once per day, no reduction in water intake was observed. If an aversive current occurs only a few times per day, it is not likely to have an adverse effect on cow behavior. The more often an aversive voltage occurs in areas critical to cows' normal feeding, drinking, or resting, the more likely it is to affect cows.

No one sign is pathognomonic; a variety of signs has been reported in cows exposed to different levels of voltage. Documented signs are behavioral changes and decreased drinks of water per day and length of time per drink (Merck, 2004). The amount of water consumed may not be affected even when behavioral modification occurs. Intermittent periods of poor performance, poor milk letdown, and incomplete or uneven milk-out, abnormal behavior during milking, increased milking time, refusal of feed or water, increased SCC in milk, and increased mastitis are signs often attributed by farmers to stray voltage; however, none of these signs were evident in numerous controlled studies. These signs are often caused by other factors such as abusive cow handling, faulty milking machine, poor milking techniques and hygiene, and nutritional deficiencies. Therefore, animal behavior or other symptoms cannot be used to diagnose stray voltage problems. The only way to determine if stray voltage is a potential cause of abnormal behaviors or poor performance is to perform electrical testing as discussed below. A thorough investigation of the entire production unit should be conducted to determine other sources of problems.

Electrical systems should comply with wiring codes and standards at all times to protect both animals and people. Whenever suggestive signs cannot be attributed to other causes, measurements should be taken to determine if a voltage potential exists, and the results recorded for future comparisons. A diagnostic confirmation of stray voltage must include a competent electrical measurement indicating at least 2 to 4 V (50 or 60 Hz, rms) between 2 points that a cow might contact, with some cows should exhibiting avoidance behaviors at this location (Lefcourt, 1991). Voltage levels may need to be monitored at different times of the day and on different days because the threshold level may be exceeded intermittently. All voltage readings should be made with a 500 to 1,000 Ω resistor across the 2 measuring leads to the cow contact points in addition to open circuit measurements. Readings without the use of a shunt resistor are meaningless. Although the resis-

Table 7-2. Recommended size[1] of free stalls as related to weights of female dairy cattle used in agricultural research and teaching

Target weight	Approximate age[2] (mo)	Free stall[3]	Tie stall[3]
118 kg (260 lb)	4	61 × 122 cm (24 × 48 in)[4]	NI[5]
182 kg (400 lb)	6	69 × 122 cm (27 × 48 in)	NI
236 kg (520 lb)	8	76 × 137 to 152 cm (30 × 54 to 60 in)	NI
327 kg (720 lb)	12	86 to 91 × 152 to 168 cm (34 to 36 × 60 to 66 in)	NI
377 kg (830 lb)	16	91 to 107 × 168 to 198 cm (36 to 42 × 66 to 78 in)	NI
454 kg (1,000 lb)	20	99 × 183 cm (39 × 72 in)	122 × 152 to 175 cm (48 × 60 to 69 in)
500 kg (1,100 lb)	24	107 × 198 to 213 cm (42 × 78 to 84 in)	122 × 160 to 175 cm (48 × 63 to 69 in)
545 kg (1,200 lb)	26	114 × 208 to 213 cm (45 × 82 to 84 in)	122 × 168 to 175 cm (48 × 66 to 69 in)
636 kg (1,400 lb)	48	122 × 213 to 218 cm (48 × 84 to 86 in)	137 × 183 cm (54 × 72 in)
727 kg (1,600 lb)	60	122 × 229 cm (48 × 90 in)	152 × 183 to 198 cm (60 × 72 to 78 in)

[1]Sizes are generally larger from midwestern sources than northeastern sources.

[2]Age of Holstein or Brown Swiss for target weights.

[3]Measurements are given as stall width times stall length. Length of stall is for the side-lunge free stall. For forward-lunge free stalls, add 30 to 45 cm (12 to 18 in) (MWPS, 1995). When brisket boards are in use, the stall bed from curb to brisket board should be 168 cm (66 in).

[4]Free stalls are not recommended for calves <4 mo (Graves and Heinrichs, 1984) or 5 mo of age (Woelfel and Gibson, 1978; MWPS, 1995).

[5]NI = not included in recommendations for dairy heifers (Woelfel and Gibson, 1978; Graves and Heinrichs, 1984; MWPS, 1985; Heinrichs and Hargrove, 1987).

tance of cow and human tissues is similar, the contact resistance is generally lower for cows than for humans, particularly if cows are in a wet environment. The resistance of a cow's body plus the contact resistance with the floor is commonly estimated as 500 Ω. This is a reasonable value for a cow standing on a wet floor. Cows standing on a dry surface will typically produce 1,000 Ω resistance or higher. Cows standing or lying on dry bedding will have a resistance many times higher than this. The resistance of a human can be as low as 1,000 Ω for wet hand-foot contact to >10,000 Ω for dry hand-foot contact. The contact voltage to produce sensation can therefore be higher for humans than for cows, depending on the conditions of the contact points. If more than 1 V (60 Hz, rms) is detected at the cow contact points, it is advisable to have a qualified electrician or the local power supplier evaluate the situation.

Bulls

The feeding (NRC, 1989) and watering (NRC, 2001) of growing and mature bulls should meet requirements of the National Research Council. Bulls should be housed in clean, well-lit, and ventilated buildings or outside in facilities that protect them from inclement conditions and allow them to remain clean and dry. Young bulls kept in small and uniform groups should be observed carefully as they mature to make certain that one or more individuals are not injured. A panel can be installed in the center of group-housing pens to allow subordinate bulls to escape aggressive behavior of dominant pen mates. Aggressive behavior increases with age, and group housing should be discontinued by around 3 yr of age. Smaller or subordinate bulls should be removed from the group, and a bull removed from a group for over a few hours should never be returned to the group. Visual and vocal social interactions with other bulls may be stressful. Space requirements for bulls are listed in Table 7-1.

The safety of humans and animals is the chief concern underlying bull management practices. By virtue of their size and disposition, bulls may be considered as one of the most dangerous domestic animals. Management procedures should be designed to protect human safety and to provide for bull welfare. Electroejaculation of bulls is sometimes necessary and should be performed by a qualified person using equipment that functions properly and is in good repair. A program of annual self-regulation should be followed for 1) semen identification and sire health auditing service and 2) minimum requirements for health of bulls producing semen for artificial insemination (Mitchell, 1992; Certified Semen Services, 2002).

EUTHANASIA

When necessary, euthanasia should be performed by trained personnel using acceptable methods established by the AVMA (2007a). The approved methods for cattle are further discussed in Chapter 2: Agricultural Animal Health Care.

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